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The Dornier R4 Giant Seaplane Resting on its Handling Truck
U. S. Army Air Service Photo

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INDEX TO CONTENTS

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ONE of the greatest distinctions that may come to an aeronautical engineer is to be honored by a request from the Royal Aeronautical Society of Great Britain to deliver an address at the annual Wilbur Wright Memorial Lecture

The Wilbur Wright Memorial Lecture has been given annually since 1912, in which year a fund was raised by public subscription in England to perpetuate, by means of an annual lecture which would mark the state of aerial science, the memory of the great American pioneer. This year the society invited Comdr. Jerome C Hunsaker, U S N., to become one of the distinguished engineers who have appeared before it in this capacity Commander Hunsaker's address, entitled "Naval Architecture in Aeronautics," strongly brings out the many analogies that exist between naval architecture and aeronautical engineering and is therefore worth careful perusal.

In addition to thus honoring the United States Navy in the person of one of its most accomplished naval constructors, the Royal Aeronautical Society has elected Dr Hunsaker an Honorary Fellow This is the first time that such a distinction has been conferred upon anyone who is not a British subject, and the great compliment will be considered as more than a richly deserved reward for the able work Commander Hunsaker has achieved in aeronautical engineering More than that, it is a recognition by the oldest aeronautical organization of the advanced position in aircraft design reached by the United States Navy during the war

The United States Navy and the aeronautical world of this country will feel a justifiable pride at being thus honored by our cousins across the sea, an honor which will contribute to knitting more closely the bonds of friendship between the two great English speaking countries.

Practical Airplane Suitcase

The problem of a suitable suitcase for airplane travel is a particularly troublesome one. In a small airplane the ordinary suitcase never seems to be quite at home. A suitcase has now been built which fits exactly into the turtleback fairing of the rear part of the fuselage Whether the suitcase will fit the needs of the traveller remains to be seen, but its semi-circular shape will fit the needs of the fuselage.

Aerial Lighthouses

It is generally recognized that the use of aircraft will not reach its full development until routes have been prepared which can be traversed at night To accomplish this it will be necessary to have means of identifying landing fields after nightfall which do not depend on moonlight, or something equally unreliable. Following the marine light house in general, a number of foreign manufacturers of lighthouses have adapted their present designs to aeronautical uses. The primary difference consists in the width of beam employed. Instead of confining the light within a zone approximately horizontal, the aerial lighthouse must extend its signal approximately to the zenith. The intensity of illumination need not be as great at altitudes as it is near the horizon however, so that the total increase in candle power is not so great as would at first appear to be necessary for the requirements of aerial navigation.

Landing Gears

One of the lessons of the recent Cape-to-Cairo flight is that the present-day landing gears are not able to cope with the difficult task of alighting on average terrain. An increase in the weight of the machine makes the problem of design more difficult, but there is no loophole for the designer of the large airplane which does not seem to have been properly taken advantage of. The increase in linear dimensions of a machine makes it possible to provide for a much greater movement of the wheels than is customary This, of course, allows the undercarriage to absorb a correspondingly greater shock without adding to the stresses set up

We may expect to see development in another direction at the coming Gordon-Bennett Race The history of airplane construction shows a steady trend away from ungainly devices, which, although effective safeguards against injury in crashes, were notorious offenders in the matter of parasite resistance During the war the dangers attending a slow flying machine exceeded those of one in which the resistance of the landing gear was kept down to a minimum, and the corresponding development was toward the retractable chassis which we may soon see in use.

Wind Screens for Airplanes

Wind screens are generally associated with airships. Airships, with their great exposed areas and their enormous dimensions, seem to be more in need of such protection, particularly when entering or leaving their hangars. Accidents with airplane hangars in high gales, particularly with open doors, have recently led to experiments on smaller screens for airplane hangars. Rectangular wooden screens of a height of the object to be screened apparently furnish complete screening effect.

Experiments have also been made at the N P L. with ring screens. A ring screen is a circular wall formed of tall screens which would be placed on the ground in the open around a number of airplanes as a temporary measure of protection in high winds. The results indicate that ring screens afford shields up to heights greater than their own, provided their diameters are not excessive. Sectional ring screens having gaps in certain positions may be as effective, or nearly so, as screens having no gaps.

These experiments will have a practical bearing on operation.

Approximating Bending Moments in Air Propellers

By Edward P. Warner

It is customary, in computing the stresses in a propeller blade, to obtain the bending moments due to air pressure by doubly integrating the lift function along the blade. Since the form of this function is, in general, unknown, the two integrations must be carried out graphically, a decidedly tedious process. If, after carrying through the work, it is found that the stresses due to bending are greater than the safe working stress of the material, the section must be strengthened, and, since this strengthening necessarily changes the aerodynamic properties, the entire work of calculating the design must be repeated and a new "blade constant" chosen.

It is evident that some simple and easily applied method of approximating the bending moments before the design is even started is much to be desired, as such a method would permit the choice of sections of such a thickness that the stress would be properly distributed, increasing gradually as the hub is approached, and yet never rising above the value which might be chosen as a safe maximum. The experienced propeller designer, with a mass of data at hand, is able to judge the necessary thickness with a fair degree of accuracy, yet even he is liable to errors of judgment when choosing sections for a propeller to work under conditions slightly different from any that ever confronted him before.

Dr. J. C. Hunsaker, in the section on Aeronautics of Marks' "Mechanical Engineers Handbook," recommends that the entire blade reaction be considered as concentrated two-thirds of the way from the hub to the blade tip. This is equivalent to the assumption that the center of gravity of the load grading diagram is two-thirds of the way out on the blades, and, while such an assumption is fairly accurate for sections near the hub, where the whole load grading diagram has to be considered as producing bending moments, it obviously is not applicable to the bending moments on sections which are themselves one-third, or even one-half, of the way out along the blade.

The method which is here described was devised to overcome all of the objections which have been mentioned, and it has been found to give results of quite surprising accuracy. In the cases where it has been checked against an accurate

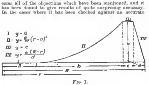


Fig. 1.

determination of the bending moments by graphical integration, the difference between the two results has never been greater than 10 per cent., and is usually less than 5 per cent. These differences are far smaller than the errors inherent in the graphical method itself and due to the fundamentally erroneous assumptions on which it rests.

In order to permit of an analytical determination of the bending moments, the load grading curve has been assumed to be made up of three straight lines and a parabola, in the manner illustrated by the sketch above. This assumption, while not by any means the most accurate that could be made, has the merit of simplicity, and is quite close enough to the truth for our present purposes.

The relative values of a, b, c, and d in the above figure, controlling as they do the shape of the diagram, cannot be so chosen as to give the best results for all blade forms. A propeller with constant blade-width, for example, should have b larger, c and d smaller, than one with very much pointed blade tips. As a single set is desired for simplicity's sake, however, the following values have been selected and will be found to give excellent results for all blade forms which are not excessively freakish.

$a = .22\ R$
$b = .20\ R$
$c = .10\ R$
$d = .08\ R$
R is the maximum radius, or one half the diameter.

In order to explain the method employed for determining e, it is necessary to make a slight digression. According to the blade element theory of design, $T = L \cos(\alpha + \gamma)$, where T is the thrust, L the lift per running foot on the blade element considered as an aerofoil, α the angle which the resultant path of the blade makes with a plane perpendicular to the propeller axis, and $\gamma = \tan^{-1}\frac{D}{L}$. Furthermore, the efficiency of an element is given by the expression: $\rho = \frac{\tan\alpha}{\tan(\alpha+\gamma)}$ neglecting the effect of indraught. We also know that, if we divide the thrust per running foot of each element by the efficiency of that element and plot $\frac{T}{\rho}$ against r, the radius the area under the resultant curve, multiplied by the number of blades, is equal to the power which must be developed by the engine, divided by the speed of the airplane.

Combining these formulas, it may be shown that $\frac{T}{\rho}$ is equal to about $1.25\ L$. The ratio is somewhat less than 1.25 for machines and propelling units in which the value of the slip function, $\frac{V}{ND}$, is large, somewhat greater than 1.25 when the slip function is unusually small. If, then, we assume $\frac{T}{\rho} = 1.25\ L$, it is obvious that the total area under our idealized load grading curve (Fig. 1) will be equal to $\frac{375P}{1.25\ nV}$, where P is the horsepower, V the speed in miles per hour, and n is the number of blades. Considering separately the three parts of the area (separated by dotted lines), we see that the total area equals $e \times R \times (20 + 10 + 04) = 34eR$.

Therefore, $e = \frac{880 \times P}{nVR} = \frac{1760P}{nVD}$

Now taking the moments of the three partial areas about the point $r = r_o$, at which bending moment is desired, and integrating, simplifying, and substituting the value just obtained for e, we have, when $.22R < r_o < .82R$: $M = \frac{de}{2}\left(R - r_o - \frac{2}{3}d\right) + ce\left(R - r_o - \frac{c}{2}d\right) + \int_{r_o}^{R-(c+d)} (r - r_o) \cdot \frac{e}{b^2} \cdot (r-a)^2 \cdot dr =$

$e\left[\frac{d}{2}\left(R - r_o - \frac{2}{3}d\right) + c\left(R - r_o - \frac{c}{2}\right) + \frac{1}{b^2}\left(\frac{b^4}{4} + \frac{(a - r_o) \cdot b^3}{3} - \frac{(r_o - a)^4}{4} - \frac{(r_o - a)^3 (a - r_o)}{3}\right)\right] = e\left[.04R(.95R - r_o) + .10R(.87R - r_o) + \frac{1}{.36R^2} \cdot \frac{(r_o - .22R)^4}{12} + .09R^2 - .20R(r_o - .22R)\right] = \frac{1760P}{nVD}$

$\cdot\left(.038R^2 - .040Rr_o + .087R^2 - .100Rr_o + .231 \cdot \frac{(r_o - .22R)^4}{R^2} + .090R^2 - .200Rr_o + .044R^2\right) = \frac{P}{nV}\left(228R - 299r_o + 203\ \frac{(r_o - .22R)^4}{R^2}\right) = \frac{PD}{nV}\left(114 - 153\frac{r_o}{R} + 29\left(\frac{r_o}{R}\right)^2 - 89\left(\frac{r_o}{R}\right)^3 + 102\left(\frac{r_o}{R}\right)^4\right)$

When $r_o < .22R$, $M = M_{.22} + \frac{150PD}{nV} \cdot (.22R - r_o)$

M, the bending moment at radius r, is therefore equal to $\frac{CPD}{nV}$, where C is a function of $\frac{r}{R}$. The values of this function have been computed and are tabulated below, and a curve of C against $\frac{r}{R}$ has also been plotted in Fig. 2.

$\frac{r}{R}$	.10	.15	.22	.30	.40	.50	.60	.70	.80
$C = \frac{MnV}{PD}$	98.7	91.3	80.6	68.8	54.0	39.6	26.1	14.5	5.7

V is given in miles per hour, P in American horsepower, and D in inches if M is desired in lb.-in.

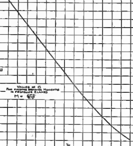


Fig. 2

This method has, of course, the same fundamental error that the graphical method has, due to the assumption that the air forces lie in the same plane all along the blade. A more accurate analysis of the stress can be made with a little additional effort, and should be carried through wherever exceptionally close results are desired.

Nurse Balloons

An interesting instance of conversion of war products to peace time pursuits is that of nurse balloons, manufactured during the Great War to feed gas to airships and kite balloons so as to eliminate the necessity of interrupting patrol duties by returning to their bases. They are now being used as gas containers in laboratories and by small gas companies where there is no need of erecting expensive metal tanks.

The Goodyear Tire & Rubber Co. manufactured many of these spherical and cylindrical type balloons during the war for use in the inflation of patrol and observation airships. The hydrogen was fed through a nursing appendix into the larger balloon. This method of storing gas allowed easy transportation both on land and water and eliminated the need for balloons interrupting their work.

These nurse balloons were easily adapted to use as gas containers, holding their original gas tightness for long periods. For companies having a small output as a by-product, or for gas manufacturers that can bottle the gas as fast as it is generated, these cylinders, which can be suspended readily in the average size room, offer excellent means of handling the gas.

Sizes and capacities of the two types follow.

Spherical Type

Capacity	Diameter
100 cu. ft.	5 ft. 6 in.
200 cu. ft.	7 ft. 3 in.
300 cu. ft.	8 ft. 3 in.
500 cu. ft.	9 ft. 10 in.

Cylindrical Type

Capacity	Length	Diameter
2,500 cu. ft.	33 ft.	10 ft. 6 in.
5,000 cu. ft.	38 ft. 6 in.	13 ft. 6 in.
10,000 cu. ft.	38 ft. 6 in.	20 ft.

Spherical Nurse Balloon, Which Can Be Used As a Gas Container for Industrial and Experimental Purposes

The Dornier Giant Flying Boats

By Eric Hildesheim

The accompanying illustrations, which have just been released for publication by the U S Army Air Service, show various types of Dornier flying boats built by the Zeppelin works

Model R1

Construction on the first Dornier giant flying boat (R1) was started at Friedrichshafen in January, 1915, and completed in October of the same year This machine (Fig 2) was a long hull flying boat with biplane wings and was fitted with three 240 hp Maybach engines driving pusher propellers

High tensile heat treated steel was used for the highly stressed members, such as the hull longitudinals, wing spars and engine gearers, the rest (ribs, hull covering, etc) being of duraluminum, except for the wing covering which was of usual fabric The top planes had four, and the bottom planes three riveted steel spars. The wing bracing was of the Warren truss type, all interplane struts running to the central spar of the bottom plane, around which the whole cellule could be rotated to adjust the incidence. The lower wings had a slight dihedral The lines of the hull were as may be seen from Fig 2, very similar to those of the Curtiss flying boats.

The Dornier R1 flying boat has a span of 143 ft 6 in., and overall length of 95 ft 9 in and an overall height of 23 ft 9 in The chord of the upper plane was 15 ft 2 in., that of the lower plane 11 ft. 10 in The total wing area was 3,600 sq ft

This machine was purely experimental and its performance of which nothing is known, did not reach the designer's expectations. Nevertheless it brought about an order for a new giant seaplane, model R2

Model R2

Model R2, begun in December, 1915 and completed in the following June, was a monoplane flying boat with a short hull and an outrigger tail, and fitted with rudimentary bottom wings. This arrangement was suggested owing to the trouble experienced with the R1, where the lower wings used to hit the sea in a swell The value as lifting surfaces of these truncated wings was small and their head resistance appreciable, therefore, when it was found that the hull possessed sufficient lateral stability on the water, these wings, which were mainly intended as side floats, were removed after the first trials.

The wings had three steel spars of triangular section and the wing struts (external bracing members) were also of steel The hull had steel frames and was covered with duraluminum plating and partly covered with fabric

The power plant originally consisted of three 240 hp Maybach engines, which were fitted in the hull and actuated three pushers through shaft and bevel gear drives. The gears gave, however, much trouble, and the power plant was therefore altered to comprise four engines of the same type which were disposed in two tandem units mounted in separate nacelles underneath the wings. These engines drove tractor and pusher airscrews directly coupled to the crankshafts. Fig 1 shows this arrangement on the modified R2, which had a monoplane instead of the biplane tail of the original R2 Four gasoline tanks of 125 gal. capacity each were carried in the hull.

The R2 had a span of 109 ft 6 in , an overall length of 78 ft. 10 in and a maximum height of 25 ft. The wing area was 2,800 sq ft and the weight empty 7.1 tons, while the useful load amounted to 2 tons. At its trials the machine attained a speed well in excess of 90 m p h

After various trials and modifications the R2 was dismantled, as much better results had in the meantime been attained by a third model, called R3

Model R3

This model differed from R2 mainly in that the wing bracing consisted of steel cables in lieu of wing struts and that the open tail booms, which were fixed to the hull, had been replaced by an enclosed fuselage secured to the top of the wings. This fuselage was built up of steel longerons and duraluminum frames and covered with fabric. In the fore part a cabin was provided for a wireless operator and two gun stations were also fitted, one fore and one aft

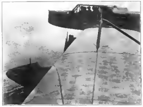
The hull was entirely constructed of duraluminum and supported on each side, on streamline steel struts, two tandem power units, each of which housed two 260 hp Maybach engines. Two pilot seats were provided in the hull, where the main gasoline tanks were also carried

The general arrangement of the Dornier R3 is shown in Fig 3 This machine, which was under construction from April to November, 1917, was delivered to the German navy by air in a 7 hr flight and served with the latter all through the rest of the war Among the many flights it carried out was one of 10 hr duration

The R3 had a span of 122 ft., and overall length of 75 ft and a maximum height of 26 ft 9 in. The total wing area was 2,500 sq ft The weight empty was 7 2 tons and the useful load 3 5 tons

Model R4

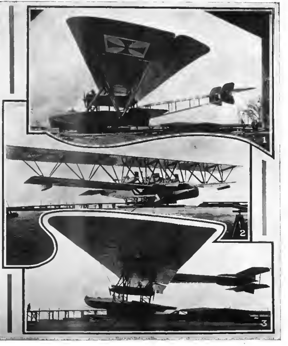
The fourth Dornier giant flying boat, Model R4, on which construction began in January, 1918, was launched shortly before the armistice It was of the same general design as Model R3 except that the hull flares out on each side in the form of fins to provide additional hydroplaning surface and



THE PILOT COCKPIT AND THE OBSERVATION CABIN ON THE DORNIER R-4 SEAPLANE
U S Army Air Service Photo

so accelerate the take-off and improve lateral stability when afloat Unlike on the R3, the tail is of the monoplane type, with a one-piece rudder The power nacelles have been made broader to improve the access to the engines in flight. Car type radiators are mounted in front of the forward engines, and the radiators of the rear ones rest above the power eggs, following earlier practice The illustrations of this machine appeared with a short descriptive notice in the February 1, 1920, issue of AVIATION AND AERONAUTICAL ENGINEERING and a new view of the cabin, taken from the port wing, is shown herewith in Fig 6.

It was stated in the issue just mentioned that this machine was to be turned over by Germany to the Inter-Allied Aeronautical Commission as a portion of the war booty. It now appears on very reliable information that rather than surrender the R3 and the R4 which embodied the latest German ideas in maritime aero construction, the German authorities towed one R boat out into the North Sea and sank her, while another machine of this type was reduced to small parts by means of sledge hammers before the Allied commission had time to intervene.



THREE MODELS OF THE DORNIER GIANT FLYING BOATS. (1) MODEL R2, (2) MODEL R1, (3) MODEL R3
U S Army Air Service Photos

This untimely end of the latest R boats prevented the Germans from carrying out their original intention of converting them into passenger carriers. However, a much smaller commercial type of flying boat was recently produced by the Zeppelin works for the Ad Astra Company, of Switzerland, and this is illustrated in Figs. 4 and 5.

Commercial Model

The Dornier Commercial Model is a monoplane flying boat which is characterized by a long hull, which carries the biplane tail, and a tandem power unit, which rests in a separate amidwings. The design of the hull is similar to that of the R4, in that it has the same aerofoil shape fins, which act both aerodynamically and hydrodynamically. From either board of

Two Views of the Dornier Commercial Flying Boat
U. S. Army Air Service Photos

these fins two steel struts run to the wings, against which they abut in the region where the aluminum plating is discontinued and fabric covering takes its place. It is understood, however, that an all-metal construction is now to be introduced.

The engine nacelle houses two 290 hp. Maybach engines in tandem arrangement, which drive a tractor and a pusher, respectively. The front part of the hull forms a cabin which accommodates from six to nine persons. The pilot is seated in a separate cockpit at the bow.

The Commercial Model is 92 ft. 5 in. in span and 49 ft. 6 in. in overall length. The weight empty is 3.3 tons and the useful load, including fuel and oil, amounts to 1 ton. A high speed of 110 m.p.h. is claimed for this machine, and the climb is given as 3,300 ft. in 10 min.—which figures, if confirmed would be a proof of high efficiency in design.

Air Mail Performance for May, 1920

The performance record of the Air Mail Service for the month of May, just issued, shows that 85 per cent of the trips between New York and Washington were completed in time; 86 per cent between New York and Cleveland; 65 per cent between Cleveland and Chicago, and 82 per cent between Chicago and Omaha.

The field average from New York to Washington was 88 per cent, from New York to Cleveland, 82 per cent, from Cleveland to Chicago, 76 per cent; and Chicago to Omaha, 88 per cent.

During the month of May, 54,693 miles were flown. Two forced landings were made on account of mechanical trouble with either motor or airplane; fifteen forced landings were due to running out of gasoline or oil in combating head winds; four were due to weather conditions and seven due to new pilots getting off course and coming down to ascertain their location.

In a circular sent to all superintendents of the Air Mail Service, Second Assistant Postmaster General Otto Praeger commends the excellent work of the pilots and calls their attention to the compilation printed below:

Field	Started on Time	Completed on Time	Without Forced Landings	Without Damage to Plane	Average for Field
N. Y.-Wash.	72%	85%	93%	100%	88%
N. Y.-Cleve.	51	86	93	98	82
Cleve.-Chi.	77	65	71	90	76
Chi.-Omaha	78	82	91	100	88

"The following explanation of the percentages in the tabulations may be helpful:

Started on Time—Plane must leave the field within 15 minutes of scheduled time to fly.

"Completed on Time—Curtiss R-4 must complete a trip at a speed of 75 miles per hour for the elapsed time between take off at initial field and set down on field of destination. Forced landing for gas or oil or any other cause is responsible for the poor showing under this head. The speed requirement for DH-4 and Glenn Martin planes is at the rate of 80 miles an hour for the elapsed time between start and finish.

"Without forced landings—Means that the flight is made without interruption for any cause, whether mechanical trouble, gas or oil reservicing, or weather, etc.

"Without damage to plane—Means without damage of any character to engine or plane in taking off, landing, taxying or in flight."

Mr. Praeger adds in his circular:—

"The records indicate that if the field managements had performed the full share of their duties in getting the mail planes off within the fifteen minutes of the scheduled time of departure, the efficiency rating for May for all divisions would have made a wonderful showing.

"The general efficiency performance on the New York-Washington and the New York-Cleveland routes was marred by the failure of the Newark field management to get the mail started within fifteen minutes of the scheduled time of departure. This field failed ten times to start its plane on time to Washington and ten times to start on time to Bellefonte during the month of May.

"This trouble exists to some degree on other fields. It can be eliminated or certainly greatly improved, if planes are promptly inspected, tested and served in the afternoon before the flight if the departure of the plane is scheduled early the following afternoon. Aside from this single serious delinquency, the pilots, mechanics and field supervisors have cause to feel proud of the record which the service made during the month of May."

Practice Fields for Reserve Aviators

So that advantages gained by American airmen in their war experiences may not be lost, the War Department has arranged that qualified aviators now holding commissions in the Officers' Reserve Corps may continue their flying training, and certain fields have been designated as active flying fields, where reserve officers may make flights by communicating with the commanding officer of the field and arranging for a time when planes will be available and military activities will permit their training.

To avail himself of this opportunity to keep in touch with the "air game," the reserve officer must apply to General Menoher, Director of the Army Air Service, in Washington, for an identification book. Whether or not advantage is taken of this offer is entirely a voluntary matter with the aviator. From time to time the Army will arrange for flying competitions, which reserve aviators may enter if they desire, and thus have opportunity to demonstrate their air proficiency in performance tests.

Fields where this policy is now in operation are Carlstrom Field, Arcadia, Fla., Kelly Field, San Antonio, Texas, Langley Field, Hampton, Va., March Field, Riverside, Cal., Mather Field, Sacramento; Mitchel Field, Mineola; Post Field, Fort Sill and Bolling Field, Washington D. C.

The Liability to Ignition of Balloon Fabrics*

By Guy Barr, B. A. B. Cc.

The tests here described were undertaken in order to obtain information in answer to the following questions —

(1) Whether the fabric sent (B 29) is liable to become ignited owing to gunfire, and the result of a smoldering wad falling on it.

(2) The best fire-proofing material to employ to prevent the fabric becoming ignited, and the effect of this material on the strength and permeability of the fabric, both when new and after weathering.

(1) The fabric was of treble cotton and rubber, and had been doped on the exterior surface with aluminum dust suspended in "soluble gun-cotton." The results of the various tests made were compared with those of similar tests performed on an ordinary yellow treble balloon fabric.

Gunfire is presumably most likely to cause ignition of the fabric at point-blank range. The duration of the flame at the mouth of a rifle may be guessed as some fraction of a second. The temperature of the flame is not likely to be appreciably higher than that of an air coal-gas blowpipe flame. It was found that three seconds exposure to the hottest of this flame was required to cause ignition of either of the fabrics. The actual size of the blowpipe flame made practically no difference to the result. Hence it is extremely improbable that rifle fire could cause ignition of the fabric.

In this connection it may be appropriate to remark that collodion is not very rapidly ignited by ordinary sources of heat. It is true that once alight the combustion is fierce, but the temperature required for ignition is not low. The small quantity of collodion in the dope is not sufficient to make any noticeable difference to the burning of the fabric.

Further, a rubbered fabric does not continue to burn if locally sparked, unless the heat supplied by the lighting agent plus that due to the small quantity of fabric consumed is sufficient to cause decomposition of the subjacent rubber. If the heat reaching the rubber is at any point too small to cause the distillation of volatile vapors therefrom, the conflagration is not transmitted to that point. The combustion of rubber requires a very much greater volume of air than that of cotton, and the supply of air being limited, the diffusion of the inflammable rubber decomposition products is the preponderating agent in the spread of the fire.

(2) Bearing in mind the above facts, it was improbable that efficient fire-proofing would be secured by any of the usual materials employed for rendering cotton non-inflammable, particularly if these could be applied only to the outer layer of cotton, the other two layers being waterproofed. This view was confirmed by soaking a piece of yellow treble fabric in a solution of alum. No difference in the resistance to the attack of a smoldering wad was observed.

The wads used for these comparisons were made by cutting out discs of cardboard of the correct diameter from a sheet of such thickness that the effect of placing one of these discs on a piece of balloon fabric was the same as that caused by wads removed from a few .303 inch cartridges.

When the treble yellow fabric was compared with B 29, it was found that the former was occasionally burnt completely through by the smoldering wad, and nearly always damaged as far as the innermost cotton layer, with B 29 the dope was not only not a source of danger in this respect, but the fabric was actually somewhat protected. A wad would occasionally damage the innermost layer, but usually the outer two layers were alone attacked, and in no case was a hole burned right through. These results were further confirmed in the presence of hydrogen confined under a pressure of about an inch-and-a-half of water by a piece of the fabric attached to a suitable vessel. In spite of repeated attempts the fabrics were not burnt through by the wad in either case, and even when, by the successive application of three or four wads, a hole had been burned, the gas which escaped did not catch fire. In fact, wads smoldering with sufficient energy to cause their complete combustion were found to be unable, at any rate in the half-dozen tests made under laboratory conditions, to ignite hydrogen or hydrogen-air mixtures.

In the above cases the damage done to the fabric by a smoldering wad was sufficient to cause a considerable local reduction of strength, together with a good deal of softening of the rubber. The position of the damage was, of course, readily visible by the blackening of the yellow fabric, but the aluminum doped B 29 showed very little trace of the incident on a cursory examination. It was only when the burnt spot was rubbed with a pencil or other moderately hard body that the white film of metallic powder was removed, and the scorching rendered visible.

The resistance to fire of these fabrics is thus somewhat small, nor can any considerable protection be expected, as was pointed out above, from any ordinary fireproofing, however efficient, applied to the different plies of cotton. On the other hand, in view of the quantity of rubber present, and of the fact that the temperature of decomposition would not be materially raised by the addition of any mineral matter unless in prohibitive amount, it seemed useless to make investigations in this direction. After consideration it was decided that the most promising method of attack lay in the provision of an outer metallic coating. The attachment of metal foil appeared to offer almost insuperable difficulties, but the following method of procedure was found to afford a very gratifying measure of resistance to ignition by smoldering —

Various inventors have, during the last few years, occupied themselves with the problem of spraying metallic coatings on to woodwork, ironwork, etc., with the idea of forming a coat to resist atmospheric influences. The latest and most practical apparatus for the purpose is one due to Schoop, some details of the use of which are given in a paper by Morcom (Institute of Metals). One of the "pistols" required for the spraying has been procured by the laboratory, the other requisites are supplies of compressed hydrogen, oxygen and air, together with a length of wire of the metal to be sprayed. The principle of the method is briefly the feeding of a wire of the metal to an oxy-hydrogen blowpipe flame, where the molten metal is atomized by a blast of air external to and concentric with the oxy hydrogen flame. The particles of molten metal are rapidly cooled by the air-blast, and reach the surface to be coated at a temperature very slightly above or possibly below their melting-point, in virtue of their velocity, and perhaps also of their high temperature, they adhere firmly to the object coated. The cooling and scattering is sufficient to ensure that no undue rise of temperature occurs on the sprayed surface. Some practice is required before the apparatus can be used satisfactorily, and the sample prepared at the laboratory does not necessarily represent the best or most uniform coating which can be applied.

A small sample of single rubbered fabric was sprayed with aluminum by this process in order to see whether the fire-proofing was of any value. It was found that a smoldering wad which would burn a hole through a treble fabric scarcely affected this sample beyond slightly softening a small portion of the rubber. The tensile strength of the sample was not affected by the spraying. It is therefore evident that the metallic particles are sufficiently small and well-cooled to do no damage to the cotton. This being the case, it is reasonable to conclude that the rubber, and hence the permeability will also be unaffected.

As regards the other properties of the coating, the following remarks may be made —

(1) The additional weight per square metre is about 100 g. in the sample prepared here. Experience in the use of the process, and possible slight modifications in the dimensions of the apparatus, air pressure, etc., will in all probability reduce this figure very considerably—e. g., our first attempt gave a coating half as heavy again as our second.

(2) The outer cotton layer may, with possible advantages from the point of view of prevention of accidental local rise of temperature during the process, be moistened thoroughly

*Reports and Memoranda, No. 178 (British) Advisory Committee for Aeronautics.

before spraying, the adherence and other properties of the coating are in no wise vitiated by this precaution.

(3) As prepared here the coating is not waterproof, and in this respect is inferior to the existing dopes, etc., when the latter are in good condition. The amount of moisture adhering will probably, however, be reduced by the use of a finer spray.

(4) Since the heat conductivity of the coating is presumably the cause of the efficient protection from fire, it appeared likely that the electrical conductivity might also be considerable. It was found that the resistance was extremely small, e. g., a 100-volt lamp burned with undiminished brilliance when the circuit included a couple of feet of the fabric of two inches in width. This point is of some interest, and perhaps of great importance in view of the conclusions reached on the question of the best method of securing practical immunity from accidents due to electrostatic charges on the envelope. The process may prove to be of use in many other fields where it is desired to improve the electrical conductivity, e. g., of a rope or board.

(5) Though the behavior of the coated fabric is very satisfactory as regards resistance to scorching and smoldering, it is not suggested that it is rendered absolutely non-inflammable. If a flame acts on the fabric for a time sufficient to cause ignition the burning of the fabric is just as energetic as when burnt without the coating.

The adiathermancy of the coated fabric has not been examined, but since the coating is fairly bright, this is probably equal or superior to that of the usual aluminum dopes. The resistance to weathering has not, of course, been examined, but should be at least as good as that of the ordinary yellow fabric.

Compressive Strength of Spruce Struts

By James E. Boyd

Technologic Paper 152 of the Bureau of Standards describes certain tests of spruce, particularly with reference to suitability for use in airplane construction. The work relates chiefly to the derivation of formulas to guide the designer and engineer.

Compression tests were made on 58 square-end and 24 round-end spruce struts of uniform cross-section approximately 1.75 inches square. The length of the struts varied from 12.025 in. (slenderness ratio 25) to 126.25 in. (slenderness ratio 250). Complete measurements showing compression, lateral deflection and load up to the ultimate, were made on all the struts, the longer struts being tested to destruction. In addition, cross bend tests were made on representative specimens to determine the modulus of elasticity, resilience, and modulus of rupture. Complete data are given for three representative struts and summaries of the results on all.

These experimental results are compared with Rankine's formula, Euler's formula and the rational formula for eccentric loading. The constants were calculated from the experimental data.

Round-End Struts.—

For round-end struts the rational formula gives the best results over the whole range, but is inconvenient to use. Rankine's Formula:—

$$\frac{P}{A} = \frac{5200}{1 + \frac{L^2}{3000r^2}} \tag{1}$$

for short struts (slenderness ratio < 80) and Euler's Formula:—

$$\frac{P}{A} = \frac{16,000,000}{\frac{L^2}{r}} \tag{2}$$

for slender struts (slenderness ratio > 80) gave results within the experimental error.

Square-End Struts.—

For square-end struts accurately fitted to rigid supports Rankine's Formula:—

$$\frac{P}{A} = \frac{5200}{1 + \frac{L^2}{12,000r^2}} \tag{3}$$

gave results within the experimental error.

This condition is almost never realized in practice so that values between those given by (3) and (1) should be used in square-end construction, depending on the manner of fixing the ends. In particular, ordinary airplane pin connections should be considered as round ends, both in the plane of the pins and at right angles to it.

In the formula given above—

P = ultimate load (lb.)
A = cross-section area (sq. in.)
L = length (in.)
r = radius of gyration in (in.)
$\frac{L}{r}$ = slenderness ratio

For testing woods for use in struts, compression tests on slender round-end struts ($\frac{L}{r} = 200$) with the use of Euler's formula gives an easy method of determining the modulus of elasticity, which agrees well with values obtained from cross-bend tests.

The results of this experimental work on spruce struts of uniform cross-section having shown the applicability to these struts of the rational formula for eccentric loading and its limiting case for central loading (Euler's formula), the analogous formulas for a certain type of tapered strut were developed.

In these struts the moment of inertia varies according to the law $I = Cx^8$, where x was the distance measured from some point beyond the end of the strut. Struts of this form approximate closely the tapered struts used in airplane construction.

The formulas for eccentric loading are complicated, but the results for central loading corresponding to Euler's formula are simple, and, by the aid of a graph, are easily applied.

A graph for this purpose is given and a number of approximate methods are discussed.—*U. S. Bureau of Standards Notes.*

A Letter

Editor, Aviation and Aeronautical Engineering:—

Mr. Merrill in his letter (Aviation, May 15) seems to desire credit for the basic ideas of a pressure gauge which was described by me in Aviation for April 15, 1920.

The Curtiss gauge was designed and built in its final form, as published, in 1918, of course, without the necessity of going to Mr. Merrill for the well known physical principles involved.

I will merely state that changing a hydrostatic head by raising or lowering a tube, changing sensitivity by changing the inclination of a tube, as well as holding a meniscus constant in pressure measurements were known and used many years before Mr. Merrill was born, both separately and in combination.

There remain then, differences in mechanical construction and virtues in consequence thereof. A reading of the two articles in question will show their complete independence. As a matter of fact, the Merrill gauge requires a knowledge of the inclination of the tube, whereas the Curtiss gauge does not. A change in inclination during a measurement would subject Mr. Merrill to considerable trouble, whereas it is of no consequence in ours. The range in his is small whereas it is large in ours. The volume of the reservoir is of consequence, theoretically, in his whereas its influence is null in ours.

If Mr. Merrill wishes full credit for having thought of anything of value, I hereby acknowledge full credit for whatever virtues his interesting gauge has. On the other hand, he is guilty of the same crime of which he accuses me in not giving credit to the inventor of the screw, of the inclined plane, of glass tubes and to all the original fellows who used gauges before he came along.

J. T. Coffin.

Aeronautic Instruments

By Mayo D. Hersey

Fig. 1. Typical Airplane Instrument Board, Showing Altimeter, Timepiece, Air-Speed Indicator, Compass, Tachometer, Pressure Gages, and Radiator Thermometer

The life-cycle of any aeronautic instrument starts with the recognition of some distinct physical measurement that has to be made in flight; then, broadly speaking, it passes through the three main stages of construction, testing, and use, and ends by revealing the need for some particular improvement or new development, at which point the cycle begins over again.

As a convenient way of arranging the available information we will consider in succession these different stages of processes, emphasizing not only the general principles involved but illustrating the latter by their application to particular instruments such as the aneroid barometer or tachometer.

1. Construction of Instruments

In classifying instruments with regard to the purpose for which they are needed a fundamental distinction may be drawn between service instruments and experimental instruments. The former class, seen in Figs. 1, 2 and 3, includes only the usual instruments forming a permanent part of the equipment; the latter class includes special instruments, usually with self recording attachments, for use in experiments on aircraft and especially for conducting performance tests on airplanes. Service instruments have to be light and rugged, fool-proof, and reliable under all conditions of flight, and must not occupy too much space in the cockpit. Experimental instruments must be extremely accurate and the self-recording feature is desirable, but there is great latitude in attaining these ends.

A further distinction may be drawn between instruments for balloon and airship use, and those for airplanes. Historically, instruments for lighter-than-air craft were the first to be developed, witness for example the origin of the aneroid barometer for aeronautic use in France in 1798. But owing to the more extensive use of airplanes during the war, the scientific elaboration of airplane instruments stands now far in advance of airship instruments. The chief characteristics of airship instruments are the relatively lower range of speed and altitude over which the mechanism has to function accurately, and the correspondingly weaker forces available to operate the movement. In addition, there are some extra instruments needed on airships, for measuring conditions relating to the air and hydrogen supply.

Finally, all aircraft instruments, whether for service or experimental use, and whether for lighter-than-air or heavier-than-air craft, may be classified with respect to the nature of the measurement made. From this viewpoint the most important groups are, first, altitude instruments; second, speed indicators; third, direction indicators; fourth, tachometers; fifth, gasoline indicators; sixth, thermometers and pressure gages for the power plant; seventh, time-pieces; eighth, oxygen apparatus; ninth, additional instruments for lighter-than-air craft.

Altitude Instruments

Taking up these nine groups in order, altitude instruments broadly considered may be regarded as covering the following species:

(a) Altimeters
(b) Barographs
(c) Thermographs and aerographs
(d) Statoscopes
(e) Rate-of-climb indicators
(f) Night altitude indicators.

The *altimeter* is in principle a common aneroid barometer with a moveable altitude scale instead of a fixed-pressure scale. For airplane use, however, the aneroid has to be made uncommonly well, otherwise the instrument will have serious errors caused by the peculiar conditions of flight, and the pointer may vibrate so much that it can hardly be read.

A typical altimeter is seen in the upper left-hand part of the instrument board picture, Fig. 1. The elements of its construction are probably familiar, comprising a stiff steel spring coupled to a thin corrugated metal vacuum box, together with a delicate transmission mechanism which multiplies the movement of the box. A dilation or contraction of the box only 0.002 or 0.003 in. causes a motion of 1 in. at the tip of the pointer. Various minor adjustments are provided, and usually a bimetallic bar forms part of the lever system,

* Abstract of a paper read before the American Society of Mechanical Engineers

serving in some measure to compensate for the influence of temperature

Barographs usually contain a tier of vacuum boxes, one on top of another, from two to five in number, with a pair of steel springs inside each box. The multiplying factor of the transmission mechanism is decidedly less than in altimeters, so that the pen arm has correspondingly greater power for tracing a firm ink line on the revolving chart.

Thermographs are intended for recording the temperature of the atmosphere at different altitudes. They have been built both with bimetallic elements and with delicate Bourdon tubes containing mercury or ether. For performance testing of air-

FIG 2 PITOT-VENTURI PRESSURE HEAD FOR AIR SPEED INDICATOR

planes direct-reading strut thermometers are more commonly used. *Aerographs* are combination recording instruments comprising hair hygrometer for humidity determination along with the barometric and thermometric elements.

Statoscopes serve to tell whether a balloon or airship is slightly ascending or descending They are remarkably sensitive, too much so to be of much use on airplanes. The statoscope in its simplest form is a thermally insulated vessel of air, connected to the external atmosphere by a glass tube containing a drop of red liquid which moves freely one way or the other in response to any minute change of external pressure In another form, the drop of indicating liquid is replaced by a sensitive metallic diaphragm and lever system.

Rate-of-climb indicators give a direct reading of the vertical speed in feet per minute The most usual types are based upon the pressure difference set up between the two ends of a capillary tube connecting a thermally-insulated air container with the external atmosphere. What is actually observed is the manometer indication of that differential pressure At first liquid manometers were used, but later a purely mechanical type involving sensitive diaphragms was developed by the Bureau of Standards.

The *night altitude indicator* is an optical projection instrument of the range-finder type, particularly valuable for seaplanes flying low over the water

Speed Indicators

Turning to the second general group, speed indicators may be subdivided somewhat as follows

(a) Air-speed indicators, pressure type
(b) Pressure heads for airspeed indicators
(c) Air-speed indicators, anemometer type
(d) Ground-speed indicators.

The *pressure type of air-speed indicator* shows the impact pressure of the air due to the motion of the aircraft and so enables the pilot to keep above his stalling speed and below the danger point due to excessive speed. It does not show the true speed relative to the atmosphere, except near sea-level unless a subsequent calculation is made to allow for the change in the air density with altitude. Such instruments consist of two parts the indicator proper which is mounted on the instrument board in the cockpit (See Fig 1), and a nozzle or pressure-head mounted out on some strut where it will catch the full force of the undisturbed atmosphere going by The indicator part measures the differential pressure generated by the pressure head and transmitted to it through some length of tubing Liquid manometers were used for the indicator early in the war, but later were superseded by various diaphragm constructions. Not only corrugated metal diaphragms, but even rubber and doped silk have been found satisfactory The pressure difference acting on the diaphragms of an air-speed indicator is far less than in the aneroid barometer, but somewhat greater than in the rate-of-climb indicator As a general principle it is of course easier to develop a satisfactory mechanism when there is a large force available to actuate it, than when the force is small, on account of the difficulties of eliminating friction.

The pitot tube and venturi tube have been tried out in a great variety of forms as *pressure heads for air-speed indicators*. A combination of the two gives the greatest differential pressure and was adopted in this country in preference to the pitot tube, in order to accelerate production of indicator mechanisms during the war Neither this combination nor the venturi by itself claims any scientific superiority over the familiar pitot tube Fig 2 shows the particular style of pitot-venturi adopted as standard by the Army. It generates a differential pressure of about 31.5 in of water at 100 m.p.h. near sea level, which in numerical magnitude is about 6.4 times the pressure given by a pitot tube

Air-speed indicators, anemometer type (or true air-speed type), are usually based on some rotating vane or Robinson cup principle and connected, either directly or through electric transmission, with a tachometer movement They are more useful than the pressure type for navigation, but even so require a previous knowledge or conjecture as to the wind velocity in order to determine the ground speed.

Absolute, or ground speed indicators have been successfully made in the visual type which gives its result by combining an observation of the angular velocity of the line of sight with a knowledge of the altitude. Some form of instrument is needed, however, which does not depend on the visibility of the ground

Direction Indicators

The third general group, direction indicators, may be subdivided as follows

(a) Compasses and turn indicators
(b) Inclinometers and banking indicators
(c) Angle-of-attack indicators
(d) Side-slip or yaw indicators
(e) Drift indicators
(f) Course-finding instruments.

Compasses may conceivably be either magnetic or gyroscopic, but the latter have not yet been successfully developed for airplanes. Magnetic compasses in common use are of the short-period type A long-period type was favored by many practical pilots because of its virtues as a turn indicator, but is no longer produced Both liquid-damped and air-damped compasses exist, and of both the flat card and vertical card constructions. *Turn indicators* have been made in both aerodynamic and gyroscopic forms. The former type measures the differential pressure between two static heads placed one at each wing tip It is therefore a purely atmospheric instrument which might read zero if the aircraft were resting in

a large portion of the atmosphere itself undergoing rotation. The gyroscopic forms show absolute rotation one type is a very sensitive indicator showing whether the aircraft is or is not turning, and whether to the right or left, while the other type is somewhat less sensitive but actually measures the rate of turning

Inclinometers are to be distinguished from banking indicators in that they measure the inclination of the aircraft to to ground, while *banking indicators* show only the departure of the aircraft from the proper banking position Except for unaccelerated flight, inclinometers can only be correct if they operate on some gyroscopic principle Gyroscopic inclinometers, whether of the simple spinning-top variety or some other, are usually of the long-period-pendulum type. They function just as a simple pendulum might if it were several thousand feet long, and so are free from the effects of transient accelerations, but not from persistent acceleration in the same direction, as with continuous flight in a circle. The most common inclinometers are liquid-filled tubes in the form of a large, triangular closed circuit, and are used for fore and aft observations When the aircraft climbs upward, the liquid seeks its level, and the liquid rises in that part of the tube which is nearest the pilot, so that the movement of the meniscus can be read on a scale The commonest form of banking indicator is a modification of the familiar spirit-level, bent into an arc of about 20 deg each side of the zero. Mechanical pendulum types also are in use.

Angle-of-attack indicators show the angle between the wing chord (say) and the direction of motion. Both weather-vane and differential-pressure types have been used, the latter like the side-slip indicator below.

Side-slip or yaw indicators show whether the aircraft is heading exactly in the direction of motion (relative to the atmosphere) or not. If the banking indicator does not show zero it can be inferred that side-slipping or skidding must exist, but this instrument is direct acting It operates by the differential pressure set up between symmetrically placed openings on the two sides of a sphere. This sphere is attached to some strut so as to head directly forward Evidently if the force of the air comes sideways, due to yaw, more pressure will be set up in one orifice than in the other The two openings are connected to the two sides of a diaphragm movement with dial and pointer

Drift indicators show the speed of drift compared to the speed of advance and involve the rotation of some reference line by the observer until it is parallel to the apparent trajectory of objects going by on the ground

Course-finding instruments as made at present are not direct-acting physical instruments but merely mechanical devices for determining the course and distance made good, by reference to data already available

Tachometers

Tachometers constitute the fourth general group All the various types serve for the sole purpose of indicating the revolutions per unit of time of the propeller shaft, with the exception of one instrument which indicates also the angular acceleration of the propeller shaft, that is, its rate of speeding up or of slowing down The diverse types of construction may be subdivided as follows

(a) Chronometric
(b) Centrifugal
(c) Magnetic
(d) Electric
(e) Air viscosity and air-pump
(f) Liquid.

The *chronometric* or clock-work type, which is the most accurate but also the most complicated, actually counts the number of revolutions that take place in a fixed time interval

The *centrifugal* type, now the most commonly used on aircraft, works on the principle of the change in position of a revolving mass due to centrifugal force acting against the restoring force of a spring

The *magnetic* type operates by the rotation of a permanent magnet near an electrically conducting disk which is mounted on the pointer spindle and controlled by a spring By virtue of induced currents, the magnet exerts a force tending to drag the disk around, thus deflecting the spring by an amount depending on the speed of rotation of the magnet.

The *electric* type consists of a magneto, geared to the engine shaft, which transmits the resulting voltage to a milli-volt meter in the cockpit which is graduated to read directly in revolutions per minute.

The *air-viscosity* type is similar to a torsion viscosimeter Any such viscosimeter measures the product of viscosity by speed of rotation. Here the viscosity of the fluid, air, is so nearly a constant that the deflection of the spring and pointer is almost directly proportional to the speed of rotation The *air-pump* type is based on the force of impact of the air against a movable vane resisted by a spring; the pump is geared to the engine shaft so that the deflection depends on the speed of rotation

The *liquid type* involves the observation of the maximum height of a liquid column or deflection of Bourdon gage which can be maintained by a centrifugal pump geared to the engine shaft By comparing the height of this column with that of a similar one heavily damped an indication of angular acceleration is also obtained. Several of the above physically different types of tachometers are each found in a variety of mechanical modifications

Gasoline Indicators

Gasoline indicators, the fifth group, comprise broadly speaking depth gages and flow meters *Depth gages* show the available gasoline supply or volume and are of two types, those based on a simple float principle and those which measure the hydrostatic pressure near the bottom of the tank. The latter form permits the indicators to be mounted in the cockpit *Flow meters* show the rate of consumption of gasoline at any instant. They have been based on the venturi principle and also on the principle of utilizing the force of impact of the stream of liquid against a movable element resisted by a spring or by gravity .

Thermometers and Pressure Gages

The sixth group comprises thermometers and pressure gages for the radiator, the lubrication system, and the gasoline tank, respectively These thermometers are of the long-

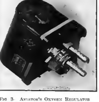


FIG 3 AVIATOR'S OXYGEN REGULATOR

distance transmission type with liquid-filled or vapor-filled bulbs. The indicator movement, installed in the cockpit, consists essentially of a Bourdon tube element, as do also the air and oil pressure gages.

Time Pieces

The seventh group, time pieces, presents no great novelty aside from the reversing stop-watches used in connection with certain bomb sights; but they have to be rugged enough to withstand airplane service and provided with suitable dials

Oxygen Apparatus

Oxygen apparatus for the aviator, group eight, may be either of the compressed oxygen, liquid, or chemical type.

Only the first has been put into regular use in this country These outfits are provided with automatic regulators which control the flow of oxygen from the storage tank to the aviator's breathing attachment. The regulators are designed to deliver an amount of oxygen which increases at the higher altitudes in accordance with a prescribed formula. The mechanism is operated by diaphragms. An example of such a regulator is shown in Fig 3

Balloon and Airship Equipment

The ninth and last group comprises balloon and airship equipment not already included among the foregoing Special pressure gages are made for indicating the amount of water ballast carried Delicate manometers are made for measuring the air pressure in the ballonnets and the hydrogen pressure in the envelope; liquid types have been used, but sensitive diaphragms are better Electric resistance thermometers are used to indicate the temperature of the gas in the envelope. Hydrogen detectors based on the action of osmotic pressure are valuable for locating leaks

Government Instrument Collection

Examples of practically all the foregoing types and some others are to be found in the government collection of aeronautic instruments, which is maintained by the Bureau of Standards at Washington. This collection is now one of the most complete in the world It contains instruments of French, British, Italian, Russian, Swiss, Danish, Dutch, German, and Austrian manufacture as well as American

(To be concluded)

The Odier Portable Starter for Aircraft Engines

Spinning air-screws is often a long and sometimes a dangerous operation. The difficulty with which even the most expert mechanics start high-powered engines has been remarked by all, and without counting the very numerous accidents of which they have been victims, this danger, one realizes, can only become greater with time, as motors are continually increasing in power. Also, many airplanes are equipped with four-bladed air screws, which are more dangerous than the two-bladed ones If the circuit breaker is defective, if the pilot makes a mistake, if the mechanic slips, or if the engine backfires, it is rare that the mechanic is not struck by the propeller

There exist many devices for automatically starting engines, which are mounted directly on the aircraft, but these represent an extra weight that is useless during flight Few of these are capable of continuous service The stationary type of Odier starter has always given satisfactory results, and its essential parts are similar to the portable type described herein A transmission mounted on an individual truck or automobile has often been tried to spin the air-screw But these devices are cumbersome, costly, and do not throw the motor over with sufficient speed What is more, when the aircraft engine backfires it imparts a very violent shock to the transmission and invariably causes considerable damage Finally, the handling of this type of apparatus is long and troublesome

The Odier starter is a small apparatus weighing 44 lb., with which one man can start without effort or danger to aircraft engines of any power Hundreds of these starters have been used on all sorts of motors such as the 130 hp Clerget, 200 hp Hispano, 400 hp Liberty, 350 hp Napier, the Rolls (Eagle) Marks VI, VII, and VIII, etc., without a single failure A Liberty was started consecutively 150 times without a miss The Messageries Aeriennes Company was only able to guarantee the departure of their postal services between Paris and Lille after having acquired a set of Odier starters. In starting off a squadron recently, six planes were started in seven minutes by an apprentice fifteen years old These examples demonstrate with what ease and certainty this device works.

A small tube containing liquified carbonic acid is connected by metal piping to a long steel cylinder containing a piston. This piston carries a pulley at its free end over which a cable is passed, with one end fastened to the cylinder and the other wrapped four times around a drum and then fastened to an elastic cord. This grooved pulley is mounted on a short shaft having a bell shaped extremity on which four bolts are placed symmetrically around the periphery in such a way that their heads project sufficiently to engage freely a standardized fitting placed already on the air-screws of all French aircraft by four bolts.

The cylinder is carried on an oblique wooden arm and an upright telescopic leg, hand adjustable so that the mechanic need not bear the weight of the device

By pressing a small lever, gas under high pressure is admitted to the cylinder, pushing the piston and tightening progressively the four spirals of cable around the grooved drum Once tight, the drum makes two revolutions with great violence The air screw is thus spun rapidly, the engine starts, and through the angle given the teeth of the propeller fitting the starter is pushed forward slightly and thereby completely disengaged. The mechanic lifts the device and carries it aside

If, through backfire, the engine reverses its sense of rotation the gas already expanded in the piston is recompressed and the elastic rolled around the grooved drum becomes slack and allows this drum (in turn coupled direct to the engine) to turn indefinitely backward without the slightest possibility of injury to either the mechanic or the mechanism If the mechanic were not to hold the device when starting the engine, the starter would be pushed forward, and if the plane were not held by wedges under the wheels, it would start forward, simply leaving the starter on the ground between the landing wheels

The construction and use of the device is as safe as it is simple Although mechanics were obliged to risk their lives frequently during the war in starting aircraft engines by hand, this practice is no longer permissible In addition to the lessened risk, and in consequence the reduced insurance policies, there is a saving of time and the number of mechanics required. The Odier starter permits an immediate departure with the assistance of one apprentice.

All Odier starters are identical, but it is necessary to indicate in orders whether the engine used turns clockwise or anti-clockwise However, it is a matter of only a few moments to reverse the sense of rotation of an Odier starter.

The carbonic acid flasks are the same as used in fire extinguishers Unused tubes remain charged indefinitely and have often been used after charging

Some Kite-Balloon Experiments*

By Griffith Brewer

At the end of 1915 I was invited to compile and deliver a course of lectures on the Theory of Ballooning at the Royal Naval Air Station at Roehampton, and for the following three years I attended regularly at Roehampton, delivering two lectures daily and setting examinations for the officers under instructions to pass into the Airship Service and into the Kite-Balloon Service.

Every encouragement was given for questions to be asked on aerostatic problems after each lecture, my endeavor being to remove as many troubles in the minds of probationers as possible The trouble which stood out above all others soon became apparent What would happen to the observers in a kite-balloon in the event of the cable breaking owing to a high wind or to its being shot through? The questions put to me showed this to be the chief cause of anxiety, and it will be seen that the causes for this anxiety were well founded. In the first place there was the danger of the balloon bursting, owing to the rapid rise causing such a great expansion of gas, as to exceed the capacity of the valve to relieve the pressure before a bursting strain had accumulated Then there was the danger of being carried into enemy territory owing to the length of time required to rise to the maximum altitude of say 8,000 ft. before equilibrium had been attained and the balloon could be brought down by valving And in the case of breaking away at sea, of being blown so far away from the ship that the exigencies of war might prevent the balloon being followed successfully.

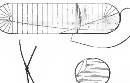


Fig. 1

If this anxiety could be removed the observers would naturally work better and concentrate their attention on their observations, without worrying about the consequences in the event of the cable breaking

Owing to the constructional difficulties and weight, the adoption of a very large valve to allow of the immediate discharge of the excess lift was out of the question, besides it would be necessary to discharge from 7,000 cu. ft. to 8,000 cu. ft. of gas in order to release the surplus lift and cause the balloon to descend, and five minutes' delay in doing this would be prohibitive. Considerable practice and good judgment would also be required in order to know when the right amount of gas had been discharged by valving

If some means could be devised for immediately releasing the surplus lift in the event of the cable breaking, the balloon could then be brought down from the captive altitude without allowing it to rise to twice or three times that altitude before commencing the descent.

The problem therefore resolved itself into ascertaining the best method of placing at the pilot's disposal the power of suddenly releasing about 500 lb of lift It was obvious that the sudden discharge of 7,000 cu ft. of hydrogen would effect this result, but that amount of gas having been discharged, the remaining 23,000 cu. ft. must be retained in order to safeguard against a dangerous speed of descent

A Drachen balloon was placed at my disposal by the Admiralty for the purpose of experiment, on the understanding that the alterations and experiments should be made at my expense and no indemnity for risk attendant on these experiments would be given.

The alterations to the balloon were then made, and consisted in dividing the balloon into two compartments by means of an internal diaphragm in the form of a parachute The aft compartment had a capacity of about 7,000 cu. ft and in this compartment a rip panel was inserted at the upper forward end A circular aperture three feet in diameter was made in the lower part of the diaphragm in order to permit of the free circulation of the gas between the forward compartment and the aft compartment, and I relied on the lift of the gas preventing the flow of the main bulk of the gas from the fore compartment after the gas should be discharged from the aft compartment.

Fig 1 illustrates the general scheme of the arrangement.

Before making the experiment I thought it advisable to test the speed of descent which could safely be taken in landing. This was done by hoisting a balloon car up to a branch of a tree and by a releasing attachment, dropping the car a measured distance to the ground The effect of the drop on a man in the car could then be observed I tried this experiment first with a fall of four feet, then five feet, and then six feet. This last fall was equivalent to a speed of fall equal to 1,200 ft. per minute and I felt satisfied with the result, but did not desire to repeat the experiment from any greater height of fall Afterwards some younger enthusiasts tried the drop from seven and eight feet, when the Commanding Officer stopped further experimental drops for fear of broken legs resulting.

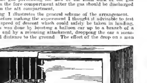


Fig. 2

Two instruments for recording landing shocks were then made as shown in Figs. 2 and 3

The apparatus illustrated in Fig 2 consists of a number of one ounce weights suspended by threads in a box. One weight is suspended by a single thread, the next by two threads, the next by three threads, and so on, increasing one thread each until the sixteenth weight is suspended by sixteen threads.

When the box is in the car of the balloon, the shock of landing breaks some of the threads and lets the weights fall to the bottom of the box. The loose weights are then removed and the box dropped from increasing measured heights until an-

* Paper read before the Royal Aeronautical Society of Great Britain

other weight breaks loose. It may then be assumed that the shock of landing was equivalent to the effect of a fall slightly less than the distance of fall in the later test

The instrument illustrated in Fig 3 shows a lead weight sliding on a rod and supported by elastic A cork is threaded on the rod and is normally held in position by friction. On the car landing, the lead weight is impelled downwards and extends the elastic and presses down the cork, which is left behind on the rod when the lead weight returns to its original position by the contraction of the elastic

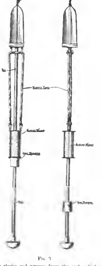


Fig 3

The first experiment was defeated by minor accidents. The balloon fitted for me at Messrs. Spencer's works, at Holloway, was inflated with air in the open, and just as we were about to enter it for the purpose of adjusting the valve, a gust of wind caught the balloon and carried it over the fence into the next field, tearing it beyond repair

The Admiralty then undertook the cost of further experiments. A second balloon was made at "Airships," at Merton, and inflated under cover, so we were able to make the necessary adjustments without risk of damage It had been decided at the Admiralty that a successful descent should first be made in ballast, before making a descent with passengers. Accordingly the balloon was inflated with hydrogen at Roehampton, and the car was loaded with ballast to represent the weight of two observers. The balloon was let up to 400 ft. and released by a slip shackle at the metallic V, and then a long rip cord was pulled—and broke. The balloon sailed away unripped and was chased it in motor cars to the Merstham Tunnel, where it descended undamaged.

The next attempt was more successful. The same balloon was inflated at Roehampton and was let up about 100 ft. The slip shackle was pulled from the ground and the rip cords, of which there were two in case one failed, were then pulled The balloon rose to about 500 ft and descended quickly, but without apparent violence The shock indicators showed the force of landing to have been equivalent to a fall of about three feet

The experiment was deemed sufficiently satisfactory, and permission was given for passengers to be carried on the next trial Accordingly on the 25 April, 1917, Maj Max Spencer and myself were let up from the winch at Roehampton to 400 ft in a wind of 21 m p.h. On pulling the release, the cable dropped and the balloon rose quickly. Then we pulled the rip panel and the balloon, after rising about another hundred feet, commenced to descend No doubt I was somewhat nervous, so finding the balloon descending quicker than we had expected we threw all our ballast and landed in Richmond Park. There was no shock, the branches of an elm tree breaking our fall completely We were on the ground fifty seconds after breaking away

The second experiment was made by Maj Dalzel and myself on the 4th, May, 1917. The balloon was released from its cable at Roehampton at an altitude of 1,200 ft After rising to 1,500 ft the rip was pulled when the speed of ascent had reached 750 ft per minute, and the descent commenced. We had previously decided that unless we were scared by the speed of fall we would throw no ballast but take the bump with knees bent We certainly came down rather hard, and the wind being rough, we dragged some distance in Richmond Park and through a stream, before we were caught by the men waiting to receive us. The time in the air was 2 min 22 sec.

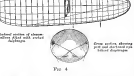
On the third experiment I was fortunate to get General Maitland to accompany me, and it was at his desire that the break away was to be made as high as the balloon would lift the cable The cable available was a heavy one and we were let up to 2,000 ft, where the balloon refused to lift more weight At this altitude in a wind of 24 m p h the release was operated and the cable dropped, being checked in its fall by a parachute attached to its top end.

The balloon then free and relieved of the weight of the cable, ascended until the speed-of-rise indicator marked 1,000 ft. per minute at 2,500 ft., and the rip was then operated As the gas escaped from the aft compartment the angle of the balloon increased from 45 deg, its normal angle, to about 80 deg when the scoop of the tail approached the car and we could look down into it and see the interior rigging As the balloon descended she slowly turned round, not quickly enough to give any sensation of giddiness, but continually changing the direction of view The wind being from the south, our course was towards the Thames, which is only a little over a mile from Roehampton R N A Station. There seemed every chance of the balloon descending in the river, so not wishing to get wet, we put out a bag of ballast at 500 ft. and another at 200 ft These saved us from the river, but not from Barnes Railway Bridge, the parachute lines of the balloon catching in the girders of the bridge and making the balloon captive, while the balloon descended on the electric railway The stationmaster at Barnes Railway Station had previously been warned of the possibility of the balloon descending on the railway, so when he saw it travelling in that direction he stopped the traffic before the actual landing took place and he then stood by the switch "to cut off the current in the event of anything happening" Nothing did happen, however, in spite of the car coming down between the two live rails, rolling first into one rail and then into the other, while the tail sat across the live and wheel rails. The balloon and the car curtsied up and down, and we had to wait patiently

for the breeze to lift us into a safer position. At last after a few minutes, which seemed much longer, we rolled over the rails to the side of the embankment, where our crew, who had run up in the meantime, caught the car and carried it to safety down the embankment and into the field beside the river. There are few insulators better than a balloon car when it is dry, and the car on this occasion was as dry as the stationmaster's remark. I venture to think that we have to thank the dryness of the car for being able at a later date to congratulate General Maitland on his wonderful voyage to America and back in R34.

These three experimental flights seemed to have broken the run of ill luck attending the first experiments, and I was now instructed to fit the invention to a streamline balloon, and, if possible, so arrange that the pilot should have the option, either of descending quickly immediately on breaking away, or of merely bringing the balloon to a state of equilibrium and then to continue as a free balloon I had already recognized that the quantity of gas discharged depended on the position of the rip panel in the aft compartment, and consequently by having two rip panels, one near the diaphragm and the other near the tail, the option of making a quick landing or of converting the balloon into a free balloon with an open neck, would be at the discretion of the pilot.

It will be seen (Fig 4) that the diaphragm has an open arch at its base completely spanning the ballonet This arch was cut out after the fourth experiment and the diaphragm as first inserted for the third experiment had two three-foot holes in its base instead The forward rip panel is close up to the diaphragm, while the aft rip is far back in the tail In the position drawn in this slide both rip panels would apparently let nearly the same quantity of gas escape, but the change in angle on the balloon becoming free increases as the gas escapes because the tail is robbed of its life and the lift then becomes concentrated in the forward end of the balloon. The aft rip panel is therefore very low in level, when the balloon is inclined in this way, and becomes equivalent to the open neck used in free spherical balloons.



Longitudinal section of streamline balloon filled with arched diaphragm

Cross section showing port and starboard rips behind diaphragm

Fig 4

When the new balloon was completed, it was decided that an attempt should be made to make a free run after checking the ascent. Maj Moore accompanied me on this occasion and we dropped the cable 100 ft. By discharge of ballast the descent was checked and a new rise commenced, and then a free run commenced exactly as in a free spherical balloon, except that during the ascents and descents the balloon gyrated slowly owing to the steering action of the deflated tail A good landing was made fifty minutes later at Rickmansworth

With the object of reducing the weight of the diaphragm I now cut the lower half into the arch form shown in Fig 4. It was now hoped to dispense with the diaphragm altogether, but I hesitated without further trials to do this at the time.

The fifth trial was made in the company of Maj Max Spencer, the balloon being first checked after ripping and then ballasted as a free balloon. The landing was made on Epsom Hills an hour or so later, the maximum altitude reached being 4,000 ft. with 100 lb ballast remaining.

The trials were then complete, and I was extremely pleased to be informed by the R N Air Department that the "Brewer Rip" was becoming a part of every naval kite-balloon and was a welcome addition from the pilot's point of view The use in the navy of the "Brewer Rip" continued for sixteen months, during which I only made one demonstration at Roehampton in the company of Col. Danville. I was then informed that the system had been discontinued at the request of the Grand Fleet on account of the additional weight involved in the diaphragm.

A new balloon was accordingly constructed with the two rips as before, but with the diaphragm completely removed, and on the 4th of October, 1918, Col Mackworth, Director of Balloons, made the first trial trip with myself in the undivided balloon. The forward of the two rips was now used for the first time and no ballast was thrown to check the drop The trial was made at Roehampton and the ground contact though fast, was not dangerously so

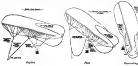


Fig 5

It was then decided to make one more trial with the aft rip only, so as to show that the undivided balloon could still make a free run.

Lieut.-Col F K McClean accompanied me. The gas in the balloon was old gas taken from another balloon and the car was over-weighted, both of us being above the average weight We also carried parachutes for the first time. The result of this flight was not what we expected, and was a poor demonstration to my class of probation officers assembled on the ground to view the ascent. The balloon rose sluggishly after being released from the cable and then after ripping fell fast, landing in some trees outside the Roehampton grounds, from which we were ignominiously rescued by our ground crew, who pulled us down from the trees.

The mishap necessitated a further trial, in which Captain Jones accompanied me This last experiment was completely successful, a free run of over an hour being made, ending up in the River Mole, near Leatherhead

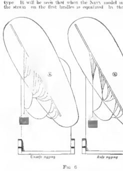
The Director of Balloons was now completely satisfied, and once again the "Brewer Rip" became standard for the Navy and for the first time also for Army balloons

Apart from the actual object in view, these experiments were instructive in many ways. In the ordinary design and use of kite-balloons, the weights and gear are assumed to suit the captive position of the balloon when flying captive on its cable. Accidental break away ascents, although fairly frequent, were always unexpected, and so opportunities to observe the change in conditions in free flight were difficult. By breaking away intentionally, we had opportunities of studying the change in conditions under less trying circumstances, and one thing we learnt was the effect of change in distribution of the car load on the rigging of kite-balloons when free.

The Navy system of running points causes the weight of the car to be carried by the forward car suspensions from eight points on each side of the balloon, i.e., 16 points in all. In the Army balloon the weight of the car is taken when the balloon is free, from one point on each side only, with the extreme probability of the attachments being torn off in succession Kite balloons should therefore be provided with running points on all the forward suspensions, although run-

ning points may be unnecessary in the central and aft points of the car suspension. (Figs. 5 and 6.)

In order to illustrate this danger in kite-balloon rigging, I have here two diagram models, one in which the points of the rigging are fixed, and the other in which the points of the rigging are free to run. In each case the forward leg of the car suspension is divided by the third bridles into two points, from which the second bridles divide into four points, and then by the first bridles into eight points which are attached to the rigging band. In the first model the points of connection are the running blocks used in Naval balloons, and in the second model these points are fixed as in the Army balloon type. It will be seen that when the Navy model is inclined, the strain on the first bridles is equalized by the running



Unsafe rigging   Safe rigging

Fig 6

blocks allowing the two arms of the bridles to change their proportion of length so as to divide the strain between them, thus allowing the eight points of attachment of the first bridles to each take its proper proportion of the weight of the car. In the Army model the whole of the strain when the model is inclined is carried on the forward bridle alone. In both models the same strength of cotton is used in the first bridles, and the weight representing the car is greater than can be supported by a single thread. By inclining the first model the weight is supported even in the extreme angular position taken up by the balloon when descending after breaking away, but in the second model, a similar inclination of the balloon bringing the weight on to each first bridle in succession breaks them one after the other and allows the car to fall. I can leave you to imagine the satisfaction we experienced when making these experiments, in observing that when the balloon became inclined to the extreme angle, we were supported by eight of these fine cords on each balloon, instead of by a single fine cord on each side only.

In conclusion, I have to thank the Admiralty for permitting me to describe this invention, which forms the subject of a secret patent which I assigned to the Admiralty. Also I cannot too gratefully acknowledge the help extended by the Director of Balloons and from the Commanding Officer and staff at Roehampton. The officers who have taken part in these experiments deserve ample recognition, for it is one thing to test one's own invention in the air, and quite another to stake one's life on the successful working of another man's invention.

N. A. C. A. Reports

The Kiln Drying of Woods for Airplanes. Synopsis of Report No 65, National Advisory Committee for Aeronautics.

This publication is a brief discussion of all of the fundamentally important phases of the subject of kiln drying lumber specifically for use in airplanes.

The exigencies of the war and scarcity of air dried material necessitated kiln drying stock immediately from the green condition. Exhaustive experiments and tests made by the Forest Products Laboratory during the last ten years have established the fact that properly kiln dried wood is just as strong, tough and stiff as the best air dried material. Douglas fir wing beams may be dried in 18 to 24 days. To air dry the same material requires 12 to 18 months. Hardwood propeller stock which requires a year or more for air drying may be satisfactorily kiln dried in 30 days. The important qualities of dried wood are freedom from checks, honeycombing, or casehardening; uniform moisture distribution, maximum strength and toughness, freedom from collapse and warping; and minimum shrinkage.

The microscopic structure of wood is briefly described, also the way in which moisture is contained in wood and the properties and behavior of wood upon removal of moisture.

Methods of controlling the circulation, humidity and temperature in the various kilns are discussed, also the use of instruments for determining actual conditions within the kiln.

The method of piling the lumber within the kiln has much to do with the factors of circulation and control of conditions. In order to know what is taking place, a suitable method of sampling and testing the material during the progress of drying must be instituted and definite records kept of the process. These points are fully discussed. Methods for removal of casehardening and prevention of mold are described.

Three articles are added in the appendix. The first is the Signal Corps specifications for kiln drying airplane stock, with an introduction explaining its origin. These specifications were prepared on July 2, 1917, by the Forest Service and have been employed without significant changes. The second article presents a constant dew point schedule for Douglas fir, spruce and similar woods. The third is a brief description of the Forest Service water spray dry kiln.

The Design of Wind Tunnels and Wind Tunnel Propellers. Synopsis of Report No 73, National Advisory Committee for Aeronautics.

The first part of this report is devoted to the study of theory of wind tunnels and wind tunnel propellers, and to an analysis of present day practice in wind tunnel propeller design. The application of the blade element method of design is also discussed. The conclusion is reached that tunnels giving a moderate air speed are in general preferable to small tunnels of very high speed. The losses in the exit cone are charted in accordance with Eiffel's investigations, a set of curves being constructed which permit the immediate determination of the approximate efficiency of a projected design of tunnel.

The latter portion of the report deals with model wind tunnel experiments, including both the efficiency of the tunnels and the regularity of distribution of airflow across the section. The conclusion is reached that the Eiffel type of tunnel is much inferior to one with a continuous closed tube.

Effect of Altitude on Radiator Performance. Synopsis of Report No 62, National Advisory Committee for Aeronautics.

The paper discusses the effect on the performance of aircraft radiators of changes in atmospheric conditions at altitudes, and a method is developed for estimating the performance at altitudes from the performance at the ground and probable atmospheric conditions. Meteorological data are included, from which atmospheric conditions at altitude may be estimated, and the method is illustrated by application to two types of radiators. The degree to which a radiator should be shuttered at altitude is considered briefly.

Copies of these reports may be obtained upon request from the National Advisory Committee for Aeronautics, Washington, D. C.

Some Lessons of the Transatlantic Flight

By Comdr. H. C. Richardson, U. S. N.
Chief Engineer, Naval Aircraft Factory, Phila. Navy Yard

One of the purposes of the transatlantic flight, and the reason the Navy Department backed it as a project and did all they could to make it go, was for the information that we were able to gain from such a flight.

The planes were originally planned to go across in war time because there was not deck room or cargo space available to send big planes across. They were designed as war craft primarily. After the war was over the transatlantic flight was planned and was carried out, as the Navy Department thought we would get information which would be of value for future work.

Navigation

The most important problem was that of navigation. Various means were devised to determine where we were. Special charts were prepared on which everything was worked out except the altitude of the body to be observed. Once that was known and the time noted, we could enter on the chart and have a graphic solution inside of two minutes to determine our position.

A great deal of thought was spent on these charts. In order to make use of them it was necessary to make use of the altitude of a heavenly body. At sea, under ordinary conditions, from an airplane the horizon is not as sharply defined as from the deck of a ship. It extends too far and gets hazy. It is a very unusual thing at any altitude from an airplane to really see a clear horizon. Consequently some device had to be used which would replace that horizon, and a sextant was developed of the bubble type which worked out fairly well.

Another method was by radio compass. We had a radio compass coil installed which was capable of handling distances of probably forty or fifty miles. For the purpose of going down a lane of destroyers only fifty miles apart it had sufficient capacity. With the apparatus we had, if some big sending station could reach us over a longer distance, it was possible to determine conditions, but the wireless apparatus was installed in a great hurry. Most of the details of the flight were planned in a great hurry and the consequence was that all details had not been completely worked out. There was not time to do it; we did not have time to measure the capacities of the craft before we left. As a result of this we found that there was a disturbance when the engine was running on account of the pulsations in the engine circuits. They affected the radio compass so that we could not get messages much over ten miles when the engines were running. And that is the reason we landed. We wanted to get a radio message over a longer distance.

Dead reckoning worked out quite satisfactorily. That was part of our problem—to determine what the course was when we had nothing to observe but waves. This was solved by using a very simple device—practically nothing but a hair that we could swing into any angle. We could note when any particle on the surface, just a little wind streak on the wave would travel along that hair, would tell us what the direction was, and it was not difficult to find out at moderate altitudes. At the higher altitudes, as you all know, the waves really "iron out"—have no individuality. As a matter of fact, sometimes at the higher altitudes, even in a storm, you can see through the surface of the sea as a mere pond, and then there is nothing to tell you what the draft is. When one gets above the clouds the surface is no longer visible at all, and you have to fall back on astronomical observations, and if the fog is deep even these are not possible.

Seaworthiness

Another thing we wanted to find out was the seaworthiness of such craft in the wind conditions to be encountered over the sea. It had been the general experience of air stations that whenever the wind came off the sea it was smooth. Going up the coast of Nova Scotia we had to travel on a definite compass course and fly with the wind nearly abeam. There was about a 45-mi. wind blowing down the hills. There were many promontories and high, rocky mountains, and besides, as it was early spring, there was hot and cold air mixed—one of the keenest things we have encountered. We ran through decidedly rough air for three hours and found that our planes were well balanced and controllable. We did not get along without any work, because after three hours of that McCullough and I were quite tired. Two days later, when we left Halifax, I was quite muscle-bound and had a hard time in using my hands to manipulate the controls. After about thirty miles they became limbered up, but I assure you that there was quite a lot of exercise during those three hours.

As to seaworthiness, we got a test which we never expected to make. As I said, we came down in order to determine our position by the radio compass. We were too far away from the destroyers to get any message while in the air. We lost contact several hours before, and we were getting no signals. We had been flying for five or six hours underneath the clouds, through squalls, fogs and rain, many times having to alter our course, and all of that contributed toward confusion in determining our position. We had gotten an observation with the sextant, but at the time we were plunging so badly that we did not have full faith in it. Later on, however, we found that that observation by the sextant was really a good one, and had we used it we probably would have found land, but, as I say, many disconcerting things had happened which caused a lack of faith in the sight that he had taken under those disadvantageous conditions, and so we decided that it was necessary to land.

Landing

When we came to land we looked at the sea and saw there were good waves running, but we had landed off Barnegat once in 10-ft. waves, and these did not look much bigger. So we landed. In making the landing the first wave we struck in a perfectly normal way. The next one, instead of being close, as we expected from the general appearance of the sea, was quite a long distance ahead of us, on account of these waves being mixed up with the ground swell. We expected by taking advantage of the decline from the crest of the wave we would make headway enough so that by the time we touched the second wave it would stay under us, but instead it dropped out from under us and dumped us on the crest of the next wave. Instead of landing on the floats we landed on the bow, and we could not resume flight.

We found that the forward engine, which was on heavy steel struts, had dropped about 8 in. and the front wings came down with it, and we realized at once that we were out of the race. We examined the hull and fortunately, although the frame supporting the bottom had been crushed in places the bottom planking, which was less than ½ in. thick, had held. Until it was determined how serious that was, we were anxious, but we soon found that the leaks were not serious. From there on we went 205 mi. in 55 hr., sailing ahead of the wind. Fortunately the wind was blowing toward the island, so that we ultimately got in. In that position we drifted all day Saturday, and Sunday morning a storm came up. At the time we had landed the wind was blowing about 25 m. p. h., the waves running 12 ft. high at times, superimposed on an 8-ft. swell, and that was really what made trouble for us. On Sunday the wind increased until it was blowing better than 60 m. p. h., the sea running 30 ft. high. We found out that our craft was seaworthy. Otherwise I would not be here. That was an unexpected test. We would not have gone out to do any such thing. In those seas we found that by keeping the plane headed into the wind she would behave satisfactorily.

Sailing

About 11 o'clock on Sunday morning we lost our left wing tip float, it just broke loose without any warning. At times on Sunday we were drifting along at an average speed of 12 knots. On the face of some of the waves we found by heading down the back of one wave and pulling up on the air controls on the face of the next that we were generally able to reach the crest of a wave before it broke. Many of the waves were so big that we saw them coming and we used every effort to gain speed down the back of one wave to get the crest of the

* Luncheon Address, April 6, 1920, Engineer Club of Philadelphia

next. In trying to get over one of these waves we stepped on the crest just as the wave broke. That naturally had the effect of converting our craft into a surf board. I think the speed at times was close to 30 m.p.h., and the water was just boiling around the hull. Under these conditions we found it essential that we should hit the waves square to the crest, because if we should yaw it would not take long to turn over, and of course our safety depended on keeping from turning over.

It was difficult to keep square to those crests because of the squalls. The wind was never in a constant direction during the highest part of the storm, sometimes the storm came from the starboard bow, and it was surprising to see the waves change direction in a very few minutes as the wind changed. Under these conditions, however, I think that we proved the planes were seaworthy. The only difficulty we had (we never took any water in the hull except through leaks, the hull was very buoyant and rode the waves beautifully) was that the crests of the waves would come up between the wing tip and the hull. This tore the cloth, and gradually the ribs themselves were turned into kindling wood. Also, due to the failure of the ribs, the cloth on the top of the wings gave way, and the sea would come over and fill the wings with water, and that had a tendency to cause us to capsize. That cloth ordinarily is very easy to cut with a knife. As a matter of fact it is no more effort than cutting paper. But when soaked with salt water it was extremely tough, and it was like cutting leather.

Emergency Tactics

We tried the use of sea anchors. At first we improvised a sea anchor. We had taken a couple of canvas buckets about 8 in. in diameter, along with us for bailing purposes. We tied two of them to a line and put them over the bow and used them all day Saturday and all day Sunday—excepting at one time Sunday, when we tried to put over the regular anchor, which was about 4 ft square—and all day Monday, until they were carried away.

On Sunday we tried the big sea anchor, but found its action was entirely to violent. We put it overboard on a 5/32-in. cable which would stand a strain of over 800 lb., and it was gone in three minutes, but the little buckets were somewhat better and helped us to head into the wind.

At another time we tried putting oil on the water, letting oil leak overboard from the engine tank, but we were running away from the oil too fast for it to do us any good. Another time we thought it would be nice to hustle into port, and we rigged up a sail, but as soon as we got it up it gave us so much starboard that we had no speed relative to the wind, and we nearly capsized.

There is one thing I think which accounts for the damage that was done to us, and that is the difference between live waves and dead waves. When we landed off Barnegat in a 10-ft. sea there was no wind at all—simply a long, glassy swell. There was no wind blowing and we had no difficulty. Of course we had no difficulty in getting off, and we got away at Barnegat without any trouble. But at the Azores those waves were alive and driven by the wind, and according to theory, they were travelling about the velocity of the wind, which was about 25 mi. an hour at the time we landed.

Another thing we learned was that when you take an emergency packet don't take it on its face value. They were about the nastiest, saltiest things I have ever tasted. We did not attempt to use them until we knew land was in sight. They are made up of round cakes about the size of a dollar, made out of corn-meal—analyzing it from my own taste—and dried fish and beans—and plenty of salt. The only thing that was good was the handsome chocolate cake in it.

Reliability of the Liberty Engine

Another lesson was the reliability of the Liberty engine. On the three planes it stood up splendidly. The only engine that was substituted from Rockaway to Plymouth, by Commander Read, was an engine that gave way, not through any fault of the engine itself, but on account of the oil tanks which supplied oil to it. That system failed near Chatham, and when it failed they shut down one engine, saw that its oil pressure was gone, and attempted to keep on with the remaining engines. They did not realize that the oil was going overboard from that tank. The result was that the forward engine ran dry and tore loose from the connecting rod and of course was out of commission. This engine at Newton with the engine that had been overhauled at Rockaway, and this replacement engine ran all the way to Plymouth, England. Aside from that, the engines on the NC-1 and NC-3 functioned thoroughly until the NC-1 and NC-3 were out of it off the Azores.

The NC-1 landed successfully, apparently in an even worse sea than we had, without any damage whatever to the plane, but a short while after landing they got a taste of seaworthiness. A squall rode them over on the wing and damaged them so badly that the one wing was put out of commission and the upper wing went into the water, so that they could not use the ailerons, which we could, and which were the means of saving the NC-3, whereas the NC-1 was lost. After they had been on the water for an hour and a half they realized that the seas were too strong to attempt to get off again. They saw a steamer off to the west and they could not make enough speed to catch her. In the meantime they had been damaged and the only way they could maintain control was to run the engines fast enough to give them rudder control. That made them drive through the seas pretty hard.

Rescue of the NC-1

About three hours later they sighted another steamer and this time the steamer was headed toward them, but they fell a little off the course, so that she would not directly get to them. Just about the time they sighted the steamer and started ahead for her a squall closed in on them and they lost sight of the steamer, but they kept on heading in the same direction for about an hour when, all of a sudden out of the fog, the Greek steamer Ionia came up almost on top of them. The quartermaster had seen the NC-1, but seeing her tore wing flapping in the air had taken it for a distress signal, and informed the captain of what he had seen, who realized that it was probably one of the planes, so he changed his course and held it until he came out of the fog, almost on top of the NC-1. In rescuing the crew he did an excellent piece of seamanship. He placed his ship broadside to the wind, lowering the lifeboat, and took all members of the NC-1 off. At times the bow of the NC-1 was 20 feet above the boat, at other times it was level with the bow. The transfer was not an easy thing to do, and it was a very nice piece of seamanship on the part of the crew and the captain. Even under these conditions, they took a line from the NC-1 when they decided to abandon her and attempted to tow her, but with the broken wing it was a hopeless task, so they had to let her go. They then took the crew of the NC-1 into port.

The NC-1 drifted all that day—all day Saturday, and until Sunday afternoon, I think it was—when she turned over. Even under those conditions she remained in those heavy seas floating until about 9 o'clock on Monday evening, when apparently the support of the empty gas tanks was no longer enough to sustain her and she disappeared under the waves.

The NC-3 was taken into Ponta Delgada. It was manifest that repairs could not be made there, so we sent her back here. Right now she is at the Navy Yard and we are waiting for a streak of good weather to go on.

Book Review

STREAMLINE KITE BALLOONS. By Capt. P. H. Sumner, R. A. F., with Useful Tables, Aeronautical and Mechanical Formulae (146 pp.) Crosby, Lockwood and Son, London.

Since the cessation of hostilities the kite balloon has passed into the background to a certain extent, no doubt largely because it has not been put to commercial uses. However, the author of the book considers that there is a commercial as well as a military future for this type of aircraft.

The development of the "sausage balloon" is outlined briefly along with descriptions of the more common types. Then follows a clear description of the various parts and their functions.

Principles and methods of design are next taken up, all but the simplest mathematics being avoided. Lift, stability and resistance are discussed in several chapters and methods of construction of the envelope and rigging are gone into at some length.

Tests of water-filled models are described and some special features of meteorological balloons.

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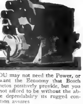

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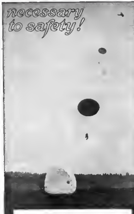

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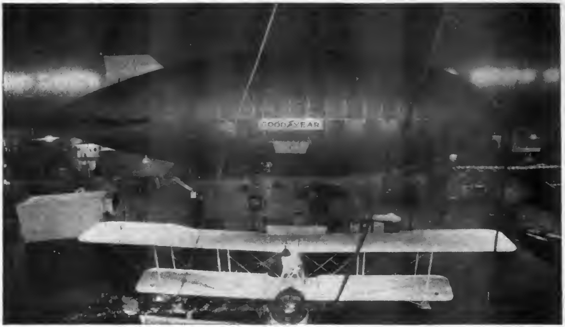

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